

FORM PTO-1390 (REV. 9-2001) Express Mailing No. EL 747 232 491 US <b>TRANSMITTAL LETTER TO THE UNITED STATES          DESIGNATED/ELECTED OFFICE (DO/EO/US)          CONCERNING A FILING UNDER 35 U.S.C. 371</b>		ATTORNEY'S DOCKET NUMBER <b>67056-002</b> U.S. APPLICATION NO (If known, see 37 CFR 1.5) <b>10/048206</b>
INTERNATIONAL APPLICATION NO. <b>PCT/GB00/02920</b>	INTERNATIONAL FILING DATE <b>July 28, 2000</b>	PRIORITY DATE CLAIMED <b>August 6, 1999</b>
TITLE OF INVENTION <b>WELDING APPARATUS AND METHOD</b>		
APPLICANT(S) FOR DO/EO/US <b>Russell Vernon Hughes</b>		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.</li> <li>4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))           <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto.</li> <li>b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</li> </ol> </li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input checked="" type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).</li> <li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol>		
<b>Items 11 to 20 below concern document(s) or information included:</b>		
<ol style="list-style-type: none"> <li>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.</li> <li>14. <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li>15. <input type="checkbox"/> A substitute specification.</li> <li>16. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.</li> <li>18. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</li> <li>19. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</li> <li>20. <input type="checkbox"/> Other items or information:</li> </ol>		

U.S. APPLICATION NO. <b>10/048206</b> INTERNATIONAL APPLICATION NO. <b>PCT/GB00/02920</b>		ATTORNEY'S DOCKET NUMBER <b>67056-002</b>	
21. <input checked="" type="checkbox"/> The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO..... <b>\$1040.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$740.00</b>  International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$710.00</b>  International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b>  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>		<b>CALCULATIONS PTO USE ONLY</b>          <b>\$ 1040.00</b>	
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		<b>\$</b>	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	<b>33 - 20 =</b>	<b>13</b>	<b>x \$18.00</b>
Independent claims	<b>2 - 3 =</b>	<b>0</b>	<b>x \$84.00</b>
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			<b>+ \$280.00</b>
<b>TOTAL OF ABOVE CALCULATIONS =</b>			<b>\$ 1274.00</b>
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.		<b>+</b>	
<b>SUBTOTAL =</b>			<b>\$ 637.00</b>
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).		<b>+</b>	
<b>TOTAL NATIONAL FEE =</b>			<b>\$ 637.00</b>
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property		<b>+</b>	
<b>TOTAL FEES ENCLOSED =</b>			<b>\$ 637.00</b>
		Amount to be refunded:	\$
		charged:	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$ <b>637.00</b> to cover the above fees is enclosed.  b. <input type="checkbox"/> Please charge my Deposit Account No. <b>50-1482</b> in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.  c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <b>50-1482</b> . A duplicate copy of this sheet is enclosed.  d. <input type="checkbox"/> Fees are to be charged to a credit card. <b>WARNING:</b> Information on this form may become public. <b>Credit card          information should not be included on this form.</b> Provide credit card information and authorization on PTO-2038.			
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR          1.137 (a) or (b)) must be filed and granted to restore the application to pending status.</b>			
SEND ALL CORRESPONDENCE TO:  <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;">           026096            Carlson, Gaskey &amp; Olds, P.C.            400 W. Maple            Suite 350            Birmingham, MI 48009            (248) 988-8360         </div> <div style="width: 45%; text-align: right;"> <div style="font-family: cursive; font-size: 1.2em; margin-bottom: 5px;">Karin Butchko</div>           SIGNATURE  <b>Karin H. Butchko</b> 1/28/02            NAME  <b>45,864</b>            REGISTRATION NUMBER  <b>Express Mail No. EL747232491US</b> </div> </div>			

#4/a

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicant: Russell Vernon Hughes  
Serial No.: Unknown  
Filed: Herewith  
Priority: PCT/GB00/02920 Filed: July 28, 2000  
GB 9918476.4 Filed: August 6, 1999  
GB 9924304.0 Filed: October 15, 1999  
Group Art Unit: Unknown  
Examiner: Unknown  
Title: WELDING APPARATUS AND METHOD

**PRELIMINARY AMENDMENT**

Box PCT  
Assistant Commissioner of Patents  
Washington, D.C. 20231

Dear Sir:

Please amend the application in the following particulars prior to Examination.

**IN THE SPECIFICATION:**

Page 1, line 2, before the first paragraph, please insert the following section heading:

**BACKGROUND OF THE INVENTION**

Page 1, line 29, before the fifth paragraph, please insert the following section heading:

**SUMMARY OF THE INVENTION**

Page 5, line 35, before the sixth full paragraph, please insert the following section heading:

**BRIEF DESCRIPTION OF THE DRAWINGS**

Page 6, line 11, before the first full paragraph, please insert the following section heading:

**DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT**

Please insert the following paragraph at the end of page 9.

The foregoing description is only exemplary of the principles of the invention. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, so that one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specially described. For that reason the following claims should be studied to determine the true scope and content of this invention.

**IN THE CLAIMS**

Please delete claims 1-48

Before the claims, please insert What is claimed is:

49. (NEW) A method of welding a plurality of overlapping members having a tenacious surface oxide layer, the method comprising the steps of:
- melting said members at a predetermined location to form a weld pool; and
  - disturbing the weld pool by introducing a disturbing member into the weld pool.
50. (NEW) The method as claimed in claim 49, wherein the step of melting the members to form the weld pool is achieved by a using a plasma arc torch.
51. (NEW) The method as claimed in claim 49, further including the step of clamping the overlapping members prior to forming the weld pool.
52. (NEW) The method as claimed in claim 49, wherein the disturbing member is consumable.
53. (NEW) The method as claimed in claim 52, wherein the disturbing member has a composition substantially similar to that of the metal forming the plurality of members.
54. (NEW) The method as claimed in claim 49, wherein the disturbing member is non-consumable.
55. (NEW) The method as claimed in claim 49, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a speed of advance and to a predetermined depth, and then withdrawing the disturbing member at a speed of withdrawal.
56. (NEW) The method as claimed in claim 55, further including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

57. (NEW) The method as claimed in claim 55, wherein the speed of advance and the speed of withdrawal of the disturbing member is variable.
58. (NEW) The method as claimed in claim 55, wherein, the speed of withdrawal is at least equal to the speed of advance.
59. (NEW) The method as claimed in claim 49, wherein movement of the disturbing member is at a relatively shallow angle to the plane of the weld.
60. (NEW) The method as claimed in claim 59, wherein the angle is greater than 30°.
61. (NEW) The method as claimed in claim 60, wherein the angle is less than 45°.
62. (NEW) The method as claimed in claim 49, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring effect.
63. (NEW) The method as claimed in claim 49, the method including disturbance of the weld pool by a welding gas.
64. (NEW) The method as claimed in claim 63, wherein the gas is caused to impinge on the weld pool at an angle and in a manner to promote swirling of the weld pool.
65. (NEW) The method as claimed in claim 49, wherein the weld pool is supported from beneath.
66. (NEW) The method as claimed in claim 50, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of the plasma arc torch.

67. (NEW) A welding apparatus for welding a plurality of overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and a weld pool distributor including a disturbing member which is movable into the weld pool to a depth sufficient to penetrate the overlapping oxide layers present in the weld pool.
68. (NEW) The apparatus as claimed in claim 67, and including a weld pool supporting member.
69. (NEW) The apparatus as claimed in claim 67, wherein the disturbing member is consumable.
70. (NEW) The apparatus as claimed in claim 69 wherein the disturbing member includes a wire having a composition substantially similar to that of the workpiece.
71. (NEW) The apparatus as claimed in claim 70, wherein the wire is movable by a feed mechanism.
72. (NEW) The apparatus as claimed in claim 71, wherein the feed mechanism is operable to move the wire at least one predetermined feed rates relative to the weld pool, in use.
73. (NEW) The apparatus as claimed in claim 71, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.
74. (NEW) The apparatus as claimed in claim 67, wherein the disturbing member is non-consumable.
75. (NEW) The apparatus as claimed in claim 68, wherein the support member comprises a support surface having a recess adapted to support the weld pool.

76. (NEW) The apparatus as claimed in claim 75, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.
77. (NEW) The apparatus as claimed in claim 68, the supporting member including a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.
78. (NEW) The apparatus as claimed in claim 68, wherein the supporting member is provided with a cooling system.
79. (NEW) The apparatus as claimed in claim 68, wherein the supporting member has a peripheral raised edge against which the work piece is received.
80. (NEW) The apparatus as claimed in claim 67, wherein the plasma arc torch and a supporting member are movable relative to one another to enable the work piece to be clamped therebetween.
81. (NEW) The apparatus as claimed in claim 67, wherein an electric welding current of the plasma torch is pulsable during welding to assist disturbance of the oxide layer



**IN THE ABSTRACT:**

Please replace the abstract with:

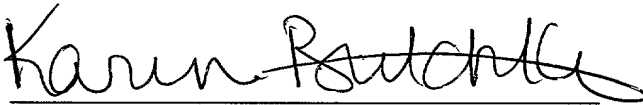
A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch, the weld pool disturbing means comprising a disturbing member which is movable into the weld pool. The apparatus may include a support member adapted to support the weld pool.

**REMARKS**

Applicant respectfully requests examination of this application.

Respectfully submitted,

**CARLSON, GASKEY & OLDS, P.C.**



Karin H. Butchko  
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(248) 988-8360

Dated: January 28, 2002

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**VERSION WITH MARKINGS TO SHOW CHANGES MADE**  
**SPECIFICATION**

Page 1, line 2, before the first paragraph, please insert the following section heading:

**BACKGROUND OF THE INVENTION**

Page 1, line 29, before the fifth paragraph, please insert the following section heading:

**SUMMARY OF THE INVENTION**

Page 5, line 35, before the sixth full paragraph, please insert the following section heading:

**BRIEF DESCRIPTION OF THE DRAWINGS**

Page 6, line 11, before the first full paragraph, please insert the following section heading:

**DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT**

Please insert the following paragraph at the end of page 7.

The foregoing description is only exemplary of the principles of the invention. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, so that one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specially described. For that reason the following claims should be studied to determine the true scope and content of this invention.

**VERSION WITH MARKINGS TO SHOW CHANGES MADE****ABSTRACT**

Please replace the abstract with:

A welding apparatus [(10)] for welding two or more overlapping members [(72, 74)] having a tenacious surface oxide layer, the apparatus [(10)] comprising a plasma arc torch [(12)] operable to form a weld pool [(80)] in a work piece [(34)], and weld pool disturbing means operable, in use, to disturb a weld pool [(80)] formed by the plasma arc torch [(12)], the weld pool disturbing means comprising a disturbing member [(56)] which is movable into the weld pool [(80)]. The apparatus [(10)] may include a support member [(58)] adapted to support the weld pool. [(80)]

[Fig. 1]

### Welding Apparatus and Method

The present invention relates to welding and in particular to welding metals having a surface oxide layer such as, for example, aluminium alloy.

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The high strength and low weight of aluminium alloy has traditionally lead to its use in areas where such factors are critical, for example in the aerospace industry. More recently it has begun to be used in the automotive industry as the material for vehicle bodies.

10

Difficulties exist in the welding of aluminium alloy due to its inherent nature. The high thermal conductivity of aluminium alloy ranges from three to five times that of steel, with the result that significantly higher inputs of energy are required to achieve fusion. For the welding of thick sections preheating of the work pieces may be necessary. Aluminium and its alloys have a surface film of aluminium oxide which forms rapidly when the aluminium is exposed to the atmosphere. It has been necessary to remove this oxide layer before welding as it prevents fusion between the work pieces. Oxide removal operations are time consuming and require a high degree of work piece cleanliness to be maintained if subsequent welding operations are to be successful. Magnesium and its alloys are also beginning to be considered for automotive applications. Like aluminium, magnesium also forms a surface oxide layer when exposed to the atmosphere.

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These inherent problems with welding aluminium, magnesium and their alloys have thus far restricted their use in the automotive industry to top of the range vehicles and have necessitated the use of less desirable alternative joining methods such as riveting and adhesives.

30

According to a first aspect of the present invention there is provided a method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:

melting said members at a predetermined location to form a weld pool; and disturbing the weld pool.

35

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The step of disturbing of the weld pool enables sufficient mixing of the molten metal of the work pieces to ensure fusion therebetween. In particular, the step of disturbing the weld pool serves to break down any layer of oxide in the weld pool which, if left undisturbed, would prevent fusion.

- 5 In a preferred embodiment the step of melting the members to form the weld pool is achieved by using a plasma arc torch. The method may include the step of clamping the overlapping members prior to forming the weld pool.
- 10 Disturbance of the weld pool may be achieved by introducing a disturbing member into the weld pool. In one embodiment the disturbing member may be consumable, for example a wire having a composition the same or similar to that of the metal forming the two or more members. In such an embodiment, the step of disturbing the weld pool may comprise the steps of advancing the disturbing
- 15 member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate. The method may include the intermediate step of holding the disturbing member in the weld pool for a predetermined time.
- 20 Preferably the speed of advance and withdrawal of the disturbing member is variable, and in a preferred embodiment the speed of withdrawal is equal to or faster than the speed of advance.
- In an alternative embodiment the disturbing member may be non-consumable,
- 25 for example a lance made from a material which is not wetted by the molten metal of the weld pool. The lance may be made from, for example platinum or a ceramic material. In such an alternative embodiment, the step of disturbing the weld pool may comprise the steps of advancing the lance into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the
- 30 lance. Again, the method may include the intermediate steps of holding the lance in the weld pool for a predetermined time.
- Disturbance of the weld pool may be caused or promoted by the action of the plasma gas and/or the shielding gas. The gas may for example impinge on the
- 35 weld pool at an angle in a manner so as to promote swirling. The plasma and/or shield gas may itself have a rotational component, for example introduced by rifling in a gas delivery jet.

The weld pool is preferably supported from beneath to avoid slumping. Such an arrangement is desirable in the case of single sided spot welding and has the additional advantage of providing control over the shape and appearance of the solidified weld. It will however be understood that welding according to the method described herein This latter aspect may be an important consideration in cases where the cosmetic appearance of the weld is important, or where a smooth surface finish is desirable.

In an alternative embodiment the support may be provided with a recess within which, in use, the weld pool is supported. The use of such a recess results in the face of the workpiece which rests there against during welding being provided with raised projections corresponding to the shape of the recess. In a run of multiple welds, the aforementioned face of the workpiece is thus provided with a repeated run of substantially identical projections. The recess may be configured so as to provide a aesthetically pleasing projection, for example a smooth dome. In an alternative embodiment the recess may be configured so as to provide a projection which is later utilisable to locate or align a component with respect to the workpiece.

If however, the weld is performed in carefully controlled conditions, a support may not be necessary. Precise regulation of the plasma gas and welding current can melt an upper layer of material whilst merely heating the lower layer. In this case the oxide layer may insulate the lower layer somewhat. As the weld pool of the upper layer is disturbed, the oxide layer is sufficiently disrupted to permit momentary melting of the lower layer, and formation of a unitary weld pool. Immediate reduction of current, plasma gas flow and/or cooling causes the weld to solidify without slumping.

In a preferred embodiment, the movement of the disturbing member is at a relatively shallow angle to the plane of the weld, preferably above  $30^\circ$  and most preferably up to  $45^\circ$ .

The disturbing member is preferably introduced into the weld pool to one side thereof, thus promoting a stirring effect which more effectively promotes mixing in the weld pool. Two or more disturbing members may be provided to promote such stirring.

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5 In a preferred embodiment a single sided spot weld between two strips of 5754 aluminium alloy required a plasma gas (Argon) flow rate of 1.5-1.8 litre per minute, and a disturbing member comprising a single filler wire of 5554 aluminium alloy and a diameter of 1.6 mm. Such a weld had a smooth appearance with an approximate overall diameter of 8 mm on the blind side and 10 mm on the front side. Needless to say, a thinner wire would require a faster rate of feed and be more likely to buckle. A thicker wire might be more difficult to feed to the weld pool because of curvature of the feed path. Typically, in the above example, a feed speed of 4m/min. and a withdrawal speed of 5m/min. are suitable. These factors are variable by the skilled man in order to obtain a optimum weld.

15 In the case of a supported weld pool, the oxide layer may be broken or disrupted by slumping the weld pool into a support recess of appropriate size. The oxide layer has no resilience, and consequently no resistance to deformation. Mixing may be promoted, by for example a swirling effect introduced by the plasma and/or shielding gas.

20 Pulsing of a welding current may also disturb the weld pool, for example by stepping an A.C. current up and down.

25 According to a second aspect of the present invention there is provided a welding apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch. Optionally a weld pool supporting member may be provided.

30 The weld pool disturbing means preferably comprise a disturbing member which is movable into the weld pool. In one embodiment the disturbing member may be consumable, and comprise a wire or filament having a composition the same or similar to that of the workpiece. In such an embodiment the wire or filament may be movable by a feed mechanism. The feed mechanism may be operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use. Preferably the feed mechanism includes guide means to guide 35 the wire or filament to a predetermined location in the weld pool. In an alternative embodiment the disturbing means may be non-consumable, and comprise a lance or like implement. The lance is preferably be made from a

material which is not wetted by the molten metal of the weld pool. More than one wire, filament or lance may be provided.

5 The support member comprises a support surface having a recess adapted to support the weld pool. In a preferred embodiment the support member is adapted to allow the recess to vent when the weld pool is formed. The support surface may be provided with one or more open channels extending from the recess. Preferably the support member is provided with a cooling system. The support member may have a substantially hollow interior through which coolant  
10 can be circulated.

The support member may have a peripheral raised edge against which the work piece is received. Such an edge, which may be discontinuous, reduces conduction of heat from the work piece to the support, and allows a relatively  
15 easily adjustable means of varying the heat transfer characteristics of the weld. The raising of the edge may be very small, and in the order of 0.05mm.

In an alternative embodiment the support member may comprise a body having an insert, the insert defining the support surface, wherein the insert is  
20 manufactured from a material having a lower thermal conductivity than the material of the body. The use of such an insert reduces the amount of heat energy transferred to the support during welding and hence reduces the energy input required from the plasma torch. The insert may be manufactured from a ceramics material, for example reaction bonded silicon nitride. Alternatively the  
25 insert may be manufactured from an electrically conductive material, for example a graphite based material.

The plasma arc torch and support member may be movable relative to one another so as to enable the work piece to be clamped therebetween.  
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In a preferred embodiment, an electric welding current may be pulsed during welding in order to disturb the oxide layer and/or to regulate the heat input to the weld. Such an arrangement may be especially useful in avoiding slumping of non-horizontal welds.  
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An embodiment of the present invention will now be described with reference to the accompanying drawings in which:



Figure 1 shows cross-sectional side view of a welding apparatus in accordance with the present invention;

Figures 2a to 2c show diagrammatic side view of a welding operation according to the present invention;

5 Figure 3 shows a perspective view of a support member according to the present invention;

Figure 4 shows a cross-sectional side view of a first alternative support member; and

10 Figure 5 shows a cross-sectional side view of a second alternative support member.

Referring firstly to figure 1 there is shown a welding apparatus, generally designated 10, adapted to produce spot welds. The welding apparatus comprises a plasma arc welding torch 12 mounted on a movable carriage 14. The carriage 14 is movable within a cylinder 16, and an outer portion of the carriage 14 carries a peripheral seal 18 which enables the carriage 14 to act as a piston. The cylinder 16 is connected to a mounting bracket 20 via a vibration absorbent compliance ring 22. The carriage 14 is movable relative to the cylinder 16 by the selective application of fluidic pressure, for example pneumatic pressure, to the cylinder 16 via apertures 24,26 provided in the wall thereof. As can be readily seen, the apertures 24,26 are provided above and below the peripheral seal 18. A porting block 28 is provided adjacent the apertures 24,26 to enable connection of a suitable source of fluidic pressure.

25 The constricting orifice 30 of the plasma torch 12 projects from the carriage 14 and is shrouded by a clamp cup 32 carried by the carriage 14. The clamp cup 32 is connected to the carriage 14 by a retaining ring 78. The clamp cup 30 serves, in use, both to clamp a work piece 34 and to ensure adequate gas shielding of the weld site. Both functions of the clamp cup 32 will be described in more detail below. The carriage 14 is provided with cooling channels 36 to allow the circulation of coolant to cool the plasma torch 12 when it is in operation. The plasma torch 12 is retained in the carriage 14 by a tubular retaining sheath 38. The sheath 38 also houses the gas and power connections 40,42 of the plasma torch 12

35 A filler wire guide, generally designated 44, is connected to the carriage 14 by a support clamp 46. The wire guide 44 comprises a curved guide tube 48 containing a liner 50, and a tapered tip 52. In the embodiment shown the guide

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5 tube 48 passes through the mounting bracket 20. As guide tube 48 is connected to the movable carriage 14 by the support clamp 46, an insulated guide bush 54 is provided in the mounting bracket 20 to allow relative movement of the guide tube 48. Filler wire 56 is movable through the wire guide 44 by an appropriate feed mechanism (not shown). Typically the filler wire is stored in the feed mechanism on a drum. The tip 52 of wire guide 44 is positioned so as to, in use, feed the filler wire 56 through an aperture 49 in the clamp cup 32.

10 A support member 58 is shown in figure 1 and also in greater detail in figure 3. The support member 58 has a support surface 60 against which the work piece 34 rests in use. The support member 58 has a substantially hollow interior into which coolant can be circulated via an inlet 62 and an outlet 63. A recess 64 is provided in the support surface 60 and two channels 66,68 extend in opposite directions from the recess 64 to the edge 70 of the support surface 60.

15 Operation of the welding apparatus 10 will now be described with reference to all of the figures. In the embodiment shown the workpiece 34 comprises two overlapping sheets 72,74 of aluminium alloy. The sheets 72,74 are positioned such that the intended position of the weld is aligned with a nominal axis 76 passing through the plasma torch 12 and the recess 64 in the support member 58 as shown in figure 1. The carriage 14 is lowered until the clamp cup 32 abuts the work piece 34, and the work piece 34 is clamped against the support member 58. This clamping action reduces the possibility of the sheets 72,74 moving relative to one another during the subsequent welding operation.

25 The welding torch 12 is then operated to produce localised melting of the work piece 34 to form a weld pool 80. The weld pool 80 is contained by the recess 64 of the support member 58 as shown in figure 2b. As the weld pool 80 forms, air present in the recess 64, which expands due to the heating of the work piece 34, vents via the channels 66,68. Without the channels 66,68, the only means of escape for the expanding air would be through the molten weld pool 80 which could result in the weld pool 80 being blown from the recess 64. The channels 66,68 also provide a means of escape for surface coatings present on the lower surface of the workpiece 34, which coatings liquefy as a result of the formation of the weld pool 80. For example the work piece 34 may be provided with a protective surface coating of wax.

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Once the weld pool 80 has formed, there remain thin layers of aluminium oxide, shown by broken lines 82 in figure 2b, between the molten metal of the respective sheets 72,74. These oxide layers 82 comprises the oxide present on the facing surfaces of each sheet 72,74. This prevents the mixing of the molten metal of the sheets 72,74, and hence prevents fusion. To overcome this, filler wire 56 is advanced into the weld pool 80 to disturb the oxide layers 82 as shown in figure 2c. Once the oxide layers 82 are penetrated by the filler wire 56, convective forces within the weld pool 80 ensure sufficient mixing of the molten sheet metal to achieve fusion. The filler wire 56 typically has a composition which is the same as that of the alloy sheets 72,74, for example a mixture of aluminium and magnesium or silicon. Once the filler wire 56 has been advanced into the weld pool 80, it is held there for a predetermined time to allow a portion thereof to melt and become incorporated in the weld. After said predetermined time has elapsed the filler wire 56 is retracted. The work piece 34 can then be unclamped and removed from the apparatus 10.

Figure 4 shows an alternative support member 58 having a peripheral raised edge 84 which defines a substantially annular support surface 60.

The recess 64 within which the weld pool is supported in use, is provided in the middle of the annular support surface 60. In use, the raised edge 84 enables an air gap 86 to be provided between the support member 58 and the workpiece 34 in the vicinity of the weld site. The air gap 86 reduces the transfer of heat from the workpiece 34 to the support member 58 during welding.

Figure 5 shows a further support member 58 having an insert 88 therein. The insert 88 is configured so as to define the above described recess 64 and vent channels 66. The insert is manufactured from a material having a lower thermal conductivity than that of the main body of the support member 58. The insert may be a high temperature non-metallic material which, in use, is not wetted by the molten metal of the weld pool. The insert may be a ceramic material such as, for example, reaction bonded silicon nitride.

The use of an insert of a material having a lower thermal conductivity advantageously may eliminate the need for the support member 58 to be cooled as less heat energy is transferred thereto during welding. It will be appreciated that heat energy transferred to the support 58 is, in effect, wasted as it is not used in the heating of the workpiece and the formation of the weld pool. Thus by

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- reducing the energy transfer to the support 58 there is a consequential reduction in the energy needed to achieve a weld. Taking the example of welding two overlapping aluminium alloy sheets each having a thickness of 1 mm and utilising a water cooled copper support has been observed to require a welding
- 5 current of around 150 amps for a duration of about 3 seconds. In contrast, by substituting an uncooled copper support having a ceramic insert a similar weld could be achieved using a welding current of around 105 amps for a duration of about 2 seconds.
- 10 Alternatively the insert may be manufactured from an electrically conductive material having a lower thermal conductivity than the main body of the support 58. Such an insert ensures that the support in its entirety is electrically conductive and thus eliminates the possibility that the electrical circuit formed, in use, between the workpiece and the plasma torch may be broken during welding.

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## Claims

1. A method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:
- 5 melting said members at a predetermined location to form a weld pool; and
- disturbing the weld pool by introducing a disturbing member into the weld pool.
- 10 2. A method as claimed in claim 1, wherein the step of melting the members to form the weld pool is achieved by using a plasma arc torch.
3. A method as claimed in claim 1 or claim 2, and including the step of clamping the overlapping members prior to forming the weld pool.
- 15 4. A method as claimed in any preceding claim, wherein the disturbing member is consumable.
5. A method as claimed in claim 4, wherein the disturbing member has a composition the same or similar to that of the metal forming the two or more members.
- 20 6. A method as claimed in any preceding claim, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate.
- 25 7. A method as claimed in claim 6, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.
- 30 8. A method as claimed in claim 6 or claim 7, wherein the speed of advance and withdrawal of the disturbing member is variable.
9. A method as claimed in claim 8, wherein, the speed of withdrawal is
- 35 equal to or faster than the speed of advance.

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10. A method as claimed in any of claims 1 to 3, wherein the disturbing member is non-consumable.
- 5 11. A method as claimed in claim 10, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.
12. A method as claimed in claim 10 or 11, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing  
10 the disturbing member.
13. A method as claimed in claim 12, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.
- 15 14. A method as claimed in any preceding claim, wherein the movement of the disturbing member is at a relatively shallow angle to the plane of the weld.
15. A method as claimed in claim 14, wherein the angle is above 30°.
- 20 16. A method as claimed in claim 14 or claim 15, wherein the angle is up to 45°.
17. A method as claimed in any preceding claim, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring  
25 effect.
18. A method as claimed in claim 17, wherein two or more disturbing members are provided to promote such stirring.
- 30 19. A method as claimed in any preceding claim, the method including disturbance of the weld pool by a welding gas.
20. A method as claimed in claim 19 when dependant upon claim 2, the method including disturbance of the weld pool by the action of a shielding gas.
- 35 21. A method as claimed in claim 19 when dependent upon claim 2, or claim 20, the method including disturbance of the weld pool by the action of a plasma gas.

22. A method as claimed in any of claims 19 to 21, wherein the gas is caused to impinge on the weld pool at an angle and in a manner so as to promote swirling of the weld pool.

23. A method as claimed in any of claims 19 to 22, wherein the gas has a rotational component achieved by rifling in a gas delivery jet or nozzle.

24. A method as claimed in any preceding claim, wherein the weld pool is supported from beneath.

25. A method as claimed in claim 2, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of a plasma arc torch.

26. A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch, the weld pool disturbing means comprising a disturbing member which is movable into the weld pool.

27. An apparatus as claimed in claim 26, and including a weld pool supporting member.

28. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is consumable

29. An apparatus as claimed in claim 28 wherein the disturbing member comprises a wire or filament having a composition the same or similar to that of the workpiece.

30. An apparatus as claimed in claim 29, wherein the wire or filament is movable by a feed mechanism.

31. An apparatus as claimed in claim 30, wherein the feed mechanism is operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use.

32. An apparatus as claimed in claim 30 or claim 31, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.
- 5 33. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is non-consumable.
34. An apparatus as claimed in claim 33 wherein the disturbing member comprises a lance or like implement.
- 10 35. An apparatus as claimed in claim 34, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.
36. An apparatus as claimed in claim 27, wherein the support member  
15 comprises a support surface having a recess adapted to support the weld pool.
37. An apparatus as claimed in claim 36, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.
- 20 38. An apparatus as claimed in claim 36 or 37, wherein the support surface is provided with one or more open channels extending from the recess.
39. An apparatus as claimed in any of claims 36 to 38, the support member comprising a body having an insert, the insert defining the support surface,  
25 wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.
40. An apparatus as claimed in claim 39 wherein the insert is a ceramic material
- 30 41. An apparatus as claimed claim 39 wherein the insert is electrically conductive.
42. An apparatus as claimed in claim 41 wherein the insert is a graphite-based  
35 material.
43. An apparatus as claimed in any of claims 36 to 42, wherein the support member is provided with a cooling system.



44. An apparatus as claimed in claim 43, wherein the support member has a substantially hollow interior through which coolant is circulatable.
- 5 45. An apparatus as claimed in any of claims 36 to 38, wherein the support member has a peripheral raised edge against which the work piece is received.
46. An apparatus as claimed in claim 45, wherein the edge is discontinuous.
- 10 47. An apparatus as claimed in any of claims 26 to 46, wherein the plasma arc torch and supporting member are movable relative to one another so as to enable the work piece to be clamped therebetween.
- 15 48. An apparatus as claimed in any of claims 26 to 47, wherein an electric welding current of the plasma torch is pulsable during welding in order to assist disturbance of the oxide layer

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## AMENDED CLAIMS

[received by the International Bureau on 27 December 2000 (27.12.00);  
original claim 26 amended; remaining claims unchanged (5 pages)]

1. A method of welding two or more overlapping members having a tenacious surface oxide layer, the method comprising the steps of:
- 5 melting said members at a predetermined location to form a weld pool;  
and  
disturbing the weld pool by introducing a disturbing member into the weld pool.
- 10 2. A method as claimed in claim 1, wherein the step of melting the members to form the weld pool is achieved by using a plasma arc torch.
3. A method as claimed in claim 1 or claim 2, and including the step of clamping the overlapping members prior to forming the weld pool.
- 15 4. A method as claimed in any preceding claim, wherein the disturbing member is consumable.
5. A method as claimed in claim 4, wherein the disturbing member has a composition the same or similar to that of the metal forming the two or more members.
- 20 6. A method as claimed in any preceding claim, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member at a predetermined rate.
- 25 7. A method as claimed in claim 6, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.
- 30 8. A method as claimed in claim 6 or claim 7, wherein the speed of advance and withdrawal of the disturbing member is variable.
9. A method as claimed in claim 8, wherein, the speed of withdrawal is equal to or faster than the speed of advance.
- 35

AMENDED SHEET (ARTICLE 19)

10. A method as claimed in any of claims 1 to 3, wherein the disturbing member is non-consumable.

5 11. A method as claimed in claim 10, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

10 12. A method as claimed in claim 10 or 11, wherein the step of disturbing the weld pool comprises the steps of advancing the disturbing member into the weld pool at a predetermined rate and to a predetermined depth, and then withdrawing the disturbing member.

13. A method as claimed in claim 12, and including the intermediate step of holding the disturbing member in the weld pool for a predetermined time.

15 14. A method as claimed in any preceding claim, wherein the movement of the disturbing member is at a relatively shallow angle to the plane of the weld.

15. A method as claimed in claim 14, wherein the angle is above 30°.

20 16. A method as claimed in claim 14 or claim 15, wherein the angle is up to 45°.

25 17. A method as claimed in any preceding claim, wherein the disturbing member is introduced into the weld pool to one side thereof to promote a stirring effect.

18. A method as claimed in claim 17, wherein two or more disturbing members are provided to promote such stirring.

30 19. A method as claimed in any preceding claim, the method including disturbance of the weld pool by a welding gas.

20. A method as claimed in claim 19 when dependant upon claim 2, the method including disturbance of the weld pool by the action of a shielding gas.

35 21. A method as claimed in claim 19 when dependent upon claim 2, or claim 20, the method including disturbance of the weld pool by the action of a plasma gas.

AMENDED SHEET (ARTICLE 19)

22. A method as claimed in any of claims 19 to 21, wherein the gas is caused to impinge on the weld pool at an angle and in a manner so as to promote swirling of the weld pool.
- 5 23. A method as claimed in any of claims 19 to 22, wherein the gas has a rotational component achieved by rifling in a gas delivery jet or nozzle.
24. A method as claimed in any preceding claim, wherein the weld pool is supported from beneath.
- 10 25. A method as claimed in claim 2, wherein the step of disturbing the weld pool includes disturbance by pulsing a welding current of a plasma arc torch.
- 15 26. A welding apparatus for welding two or more overlapping members having a tenacious surface oxide layer, the apparatus comprising a plasma arc torch operable to form a weld pool in a work piece, and weld pool disturbing means operable, in use, to disturb a weld pool formed by the plasma arc torch, and thereby enable mixing of the weld pool to break down the surface oxide layer present therein, the weld pool disturbing means comprising a disturbing member which is movable into the weld pool.
- 20 27. An apparatus as claimed in claim 26, and including a weld pool supporting member.
- 25 28. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is consumable.
29. An apparatus as claimed in claim 28 wherein the disturbing member comprises a wire or filament having a composition the same or similar to that of the workpiece.
- 30 30. An apparatus as claimed in claim 29, wherein the wire or filament is movable by a feed mechanism.
- 35 31. An apparatus as claimed in claim 30, wherein the feed mechanism is operable to move the wire or filament at one or more predetermined feed rates relative to the weld pool, in use.

AMENDED SHEET (ARTICLE 19)

32. An apparatus as claimed in claim 30 or claim 31, wherein the feed mechanism includes guide means to guide the wire or filament to a predetermined location in the weld pool.

33. An apparatus as claimed in claim 26 or claim 27, wherein the disturbing member is non-consumable.

34. An apparatus as claimed in claim 33 wherein the disturbing member comprises a lance or like implement.

35. An apparatus as claimed in claim 34, wherein the disturbing member is made from a material which is not wetted by the molten metal of the weld pool.

36. An apparatus as claimed in claim 27, wherein the support member comprises a support surface having a recess adapted to support the weld pool.

37. An apparatus as claimed in claim 36, wherein the support member is adapted to allow the recess to vent when the weld pool is formed.

38. An apparatus as claimed in claim 36 or 37, wherein the support surface is provided with one or more open channels extending from the recess.

39. An apparatus as claimed in any of claims 36 to 38, the support member comprising a body having an insert, the insert defining the support surface, wherein the insert is manufactured from a material having a lower thermal conductivity than the material of the body.

40. An apparatus as claimed in claim 39 wherein the insert is a ceramic material

41. An apparatus as claimed in claim 39 wherein the insert is electrically conductive.

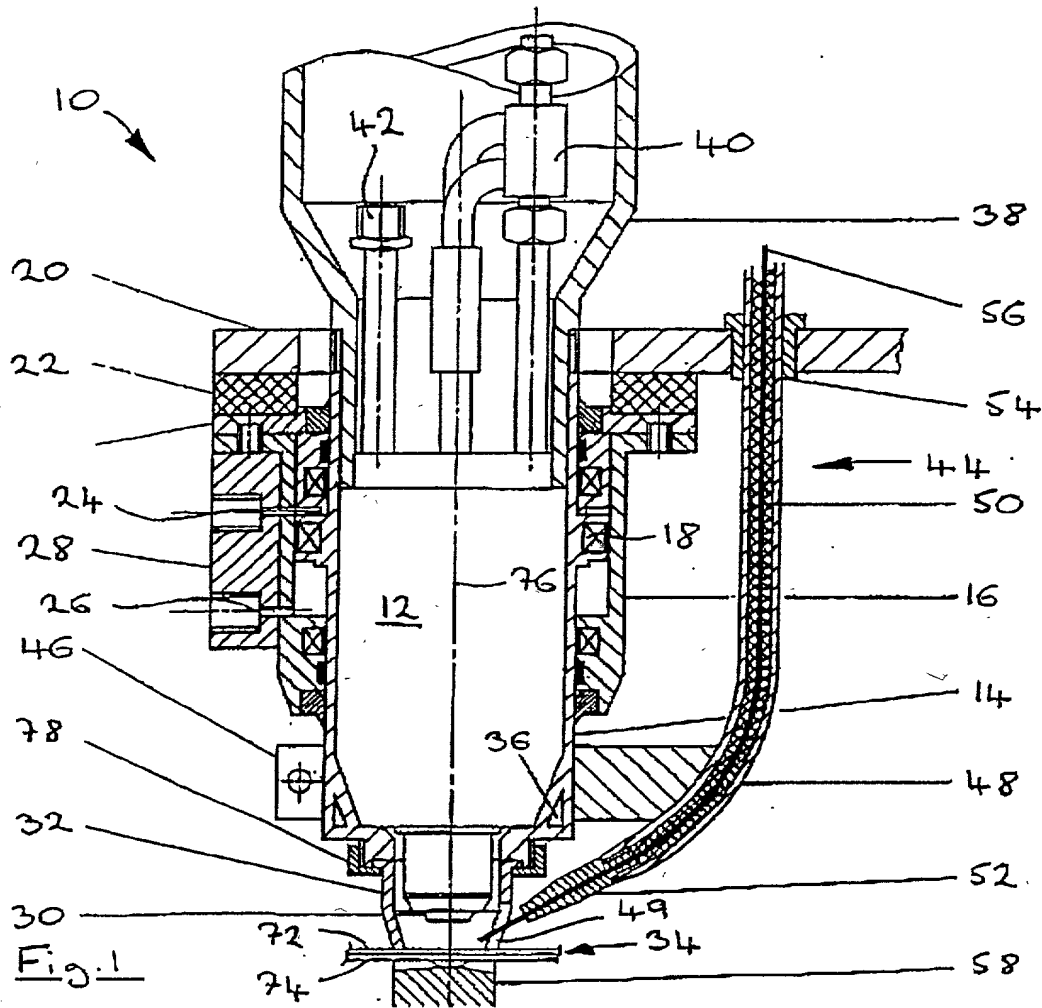
42. An apparatus as claimed in claim 41 wherein the insert is a graphite based material.

AMENDED SHEET (ARTICLE 19)

43. An apparatus as claimed in any of claims 36 to 42, wherein the support member is provided with a cooling system.
44. An apparatus as claimed in claim 43, wherein the support member has a substantially hollow interior through which coolant is circulatable.
45. An apparatus as claimed in any of claims 36 to 38, wherein the support member has a peripheral raised edge against which the work piece is received.
46. An apparatus as claimed in claim 45, wherein the edge is discontinuous.
47. An apparatus as claimed in any of claims 26 to 46, wherein the plasma arc torch and supporting member are movable relative to one another so as to enable the work piece to be clamped therebetween.
48. An apparatus as claimed in any of claims 26 to 47, wherein an electric welding current of the plasma torch is pulsable during welding in order to assist disturbance of the oxide layer

AMENDED SHEET (ARTICLE 19)





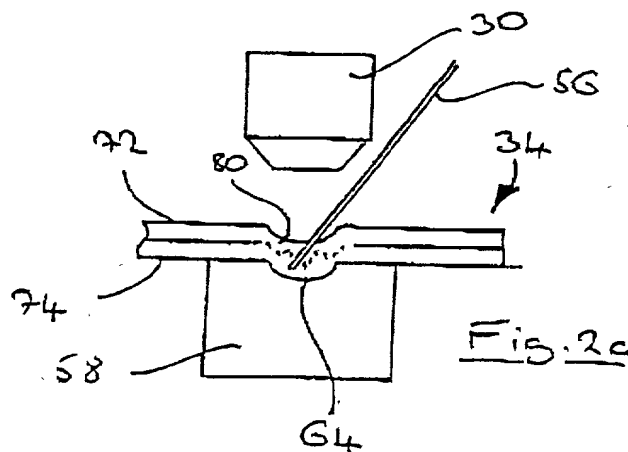
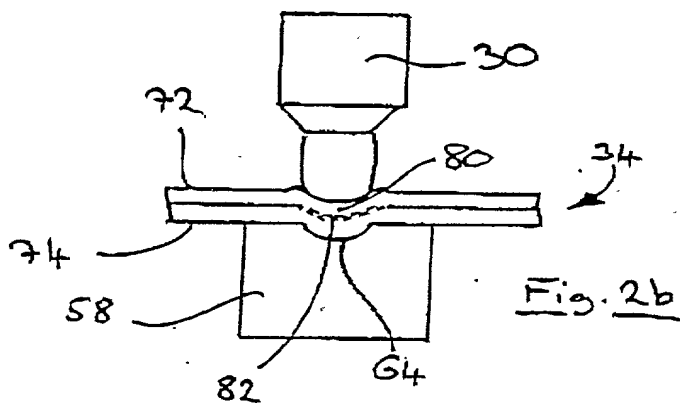
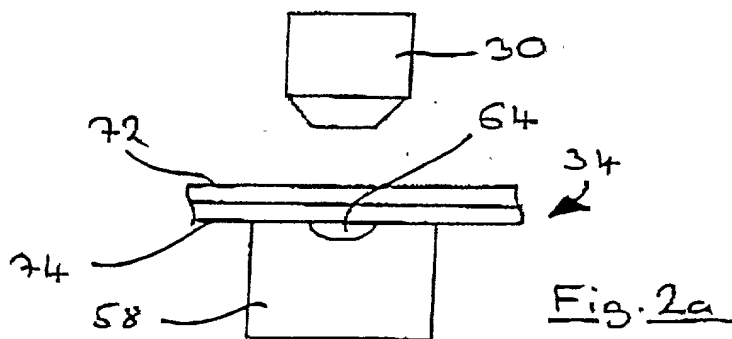
SUBSTITUTE SHEET (RULE 26)



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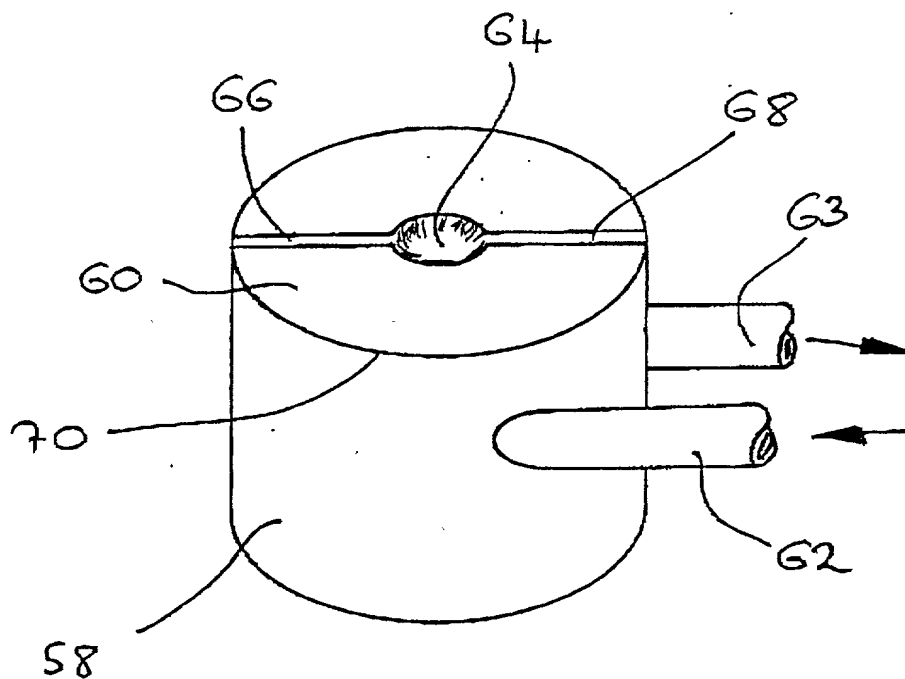
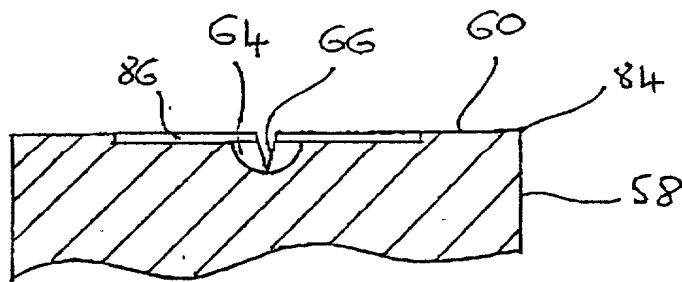
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Fig. 3Fig. 4

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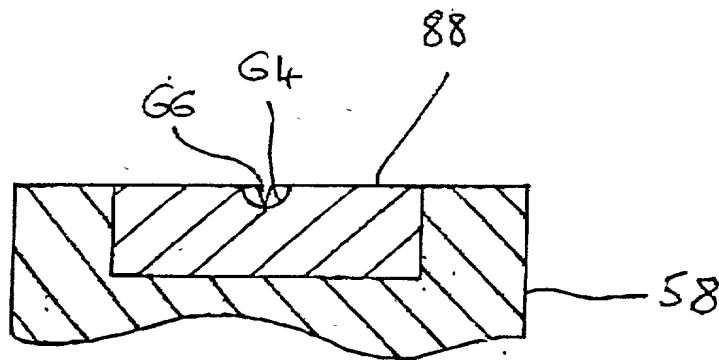


Fig. 5

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# DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

- ☐ Declaration Submitted with Initial Filing      OR      ☒ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number 67056-002

First Named Inventor Russell Vernon Hughes

**COMPLETE IF KNOWN**

Application Number 10 / 048,206

Filing Date January 28, 2002

Group Art Unit Unknown

Examiner Name Unknown

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WELDING APPARATUS AND METHOD

(Title of the Invention)

the specification of which

☐ is attached hereto

OR

☒ was filed on (MM/DD/YYYY) 01/28/2002

as United States Application Number or PCT International

(if applicable).

Application Number 10/048,206

and was amended on (MM/DD/YYYY)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES NO	
PCT/GB00/02920	WIPO	07/28/2000	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
GB 9918476.4	Great Britain	08/06/1999	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
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☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

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[Page 1 of 2]

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☐ A petition has been filed for this unsigned inventor

Given Name

(first and middle [if any])

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Family Name

or Surname Hughes

Inventor's  
Signature

Date

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☐ Additional inventors are being named on the \_\_\_\_ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

